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Interpreting wind energy resource visualisations for South Africa

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Interpreting wind energy resource visualisations for South Africa

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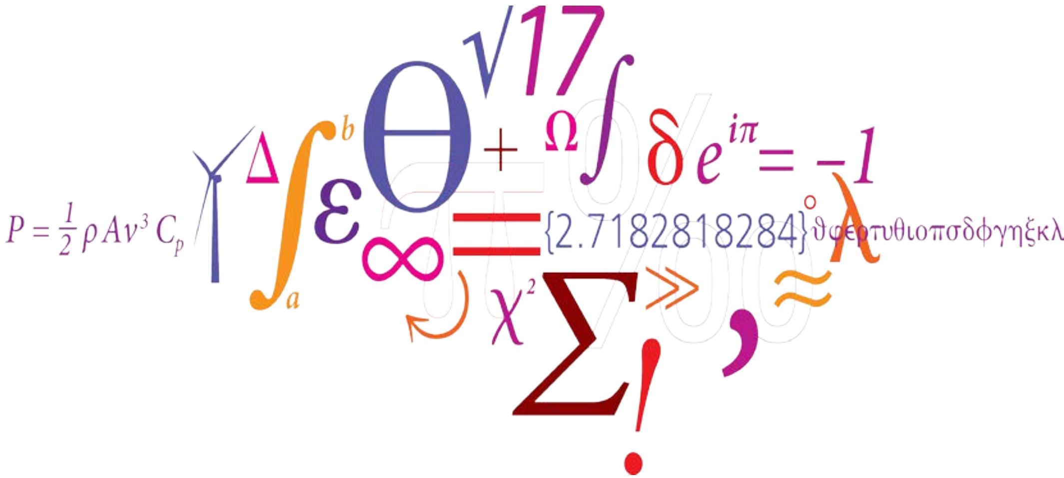
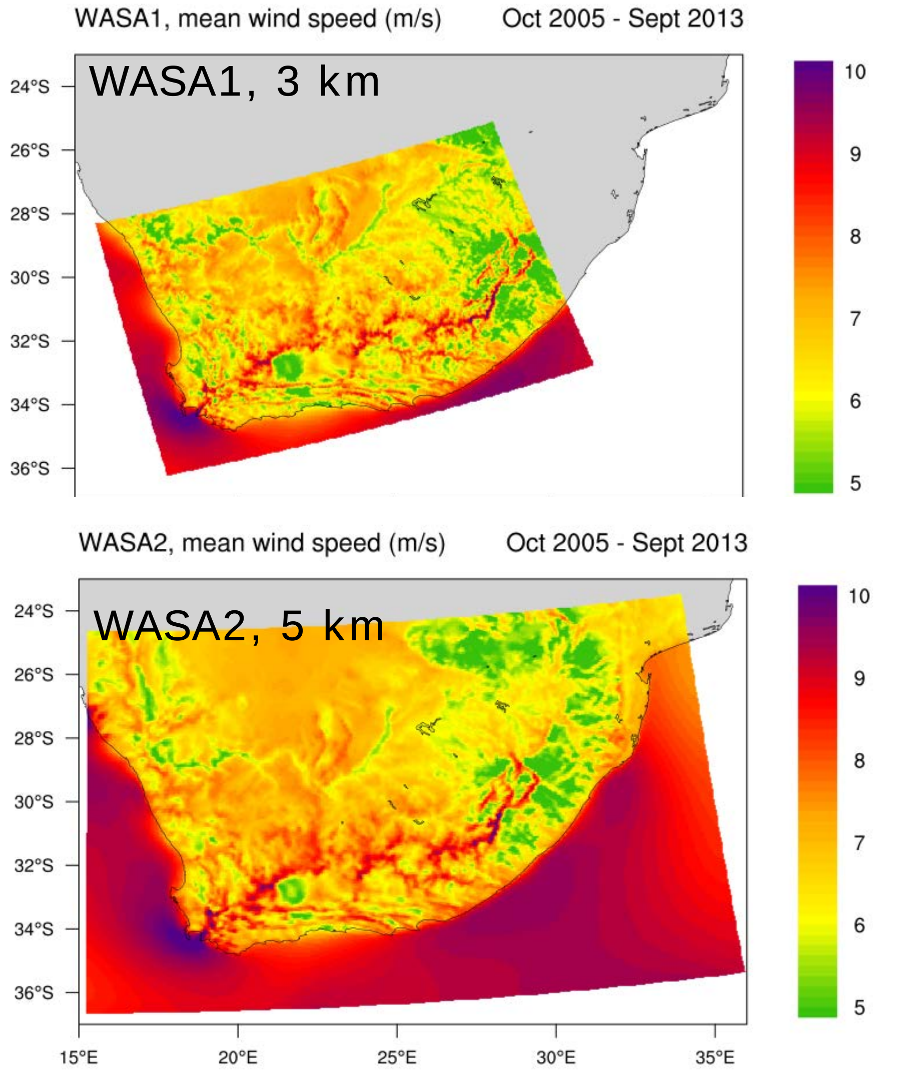


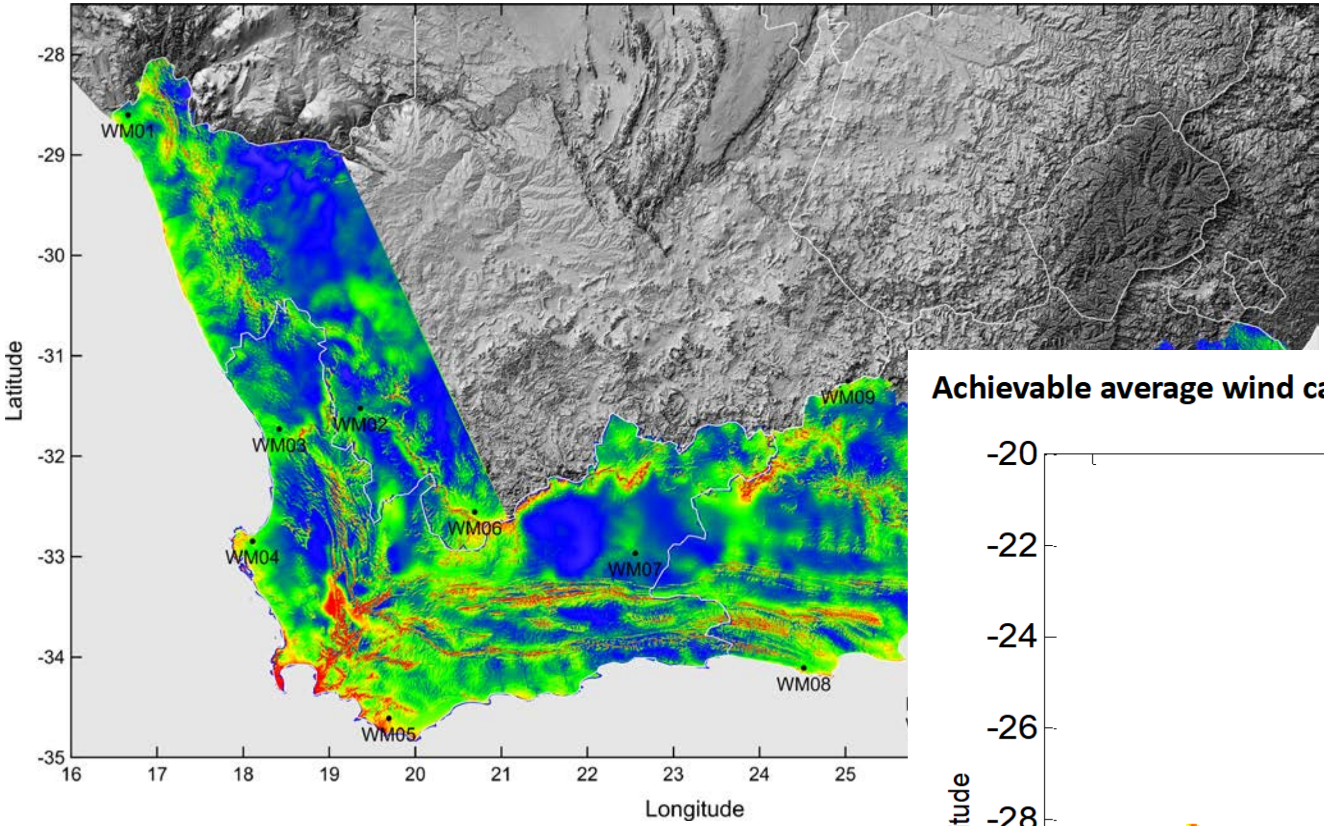
Motivation

- The WASA1/2 project ran mesoscale model simulations to create a database of the mesoscale wind climatology over South Africa.
- These data have been downscaled to produce high-resolution maps of mean wind speed and power density (see WASA banner and presentation at Windaba Wednesday afternoon).
- In 2015, DTU ran similar simulations that were used in two studies presented in WindAC last year:
  - CSIR study of Wind and Solar PV Resource Aggregation (Bischof-Niemz 2016) and
  - Wind Power Variability and Power System Reserves (Sørensen 2016).



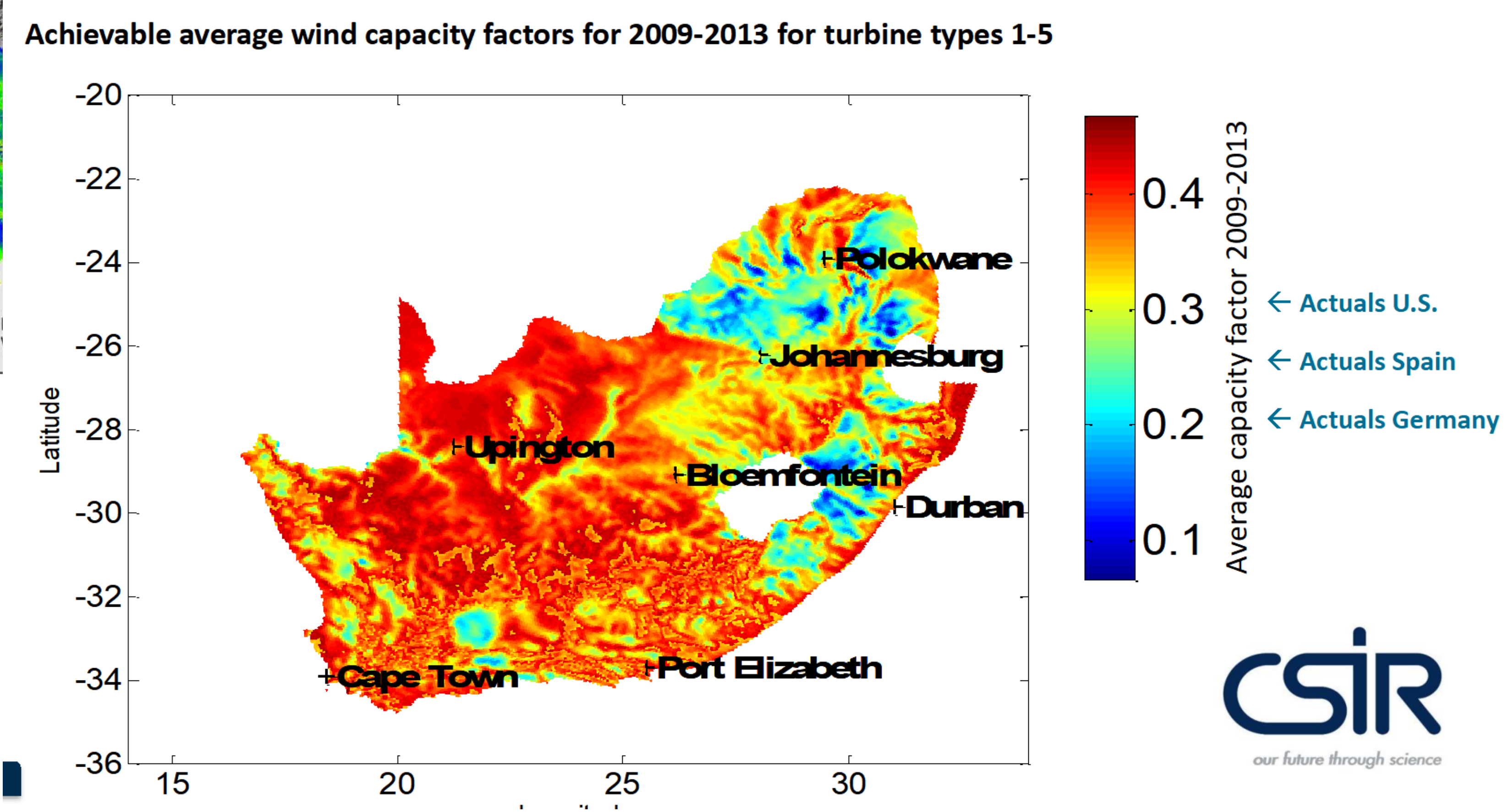
Wind resource in South Africa: On par with solar, WindAC 2016 presentation

(Bischof-Niemz et al 2016)



WASA1, mean power density at 100 m AGL

(Mortensen et al 2014)



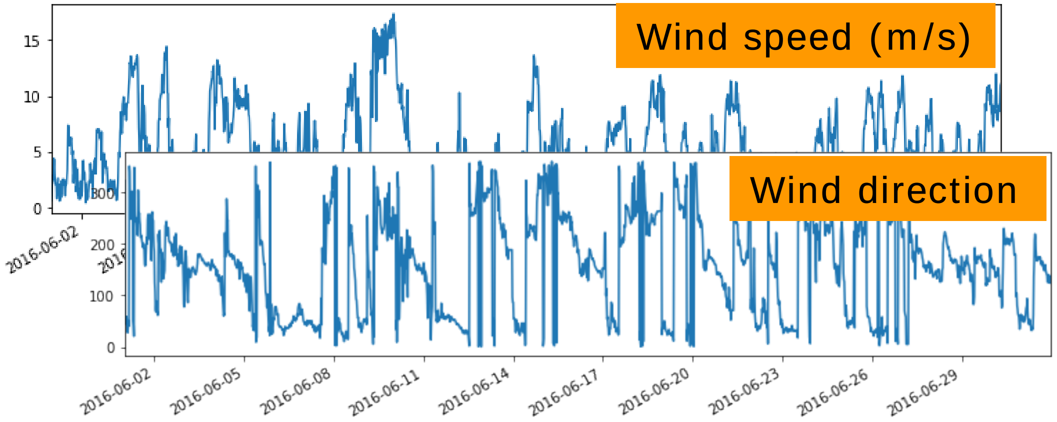
Motivation

- While all studies use the same type of base data, the results and visualization appear to show significant discrepancies that can cause confusion.

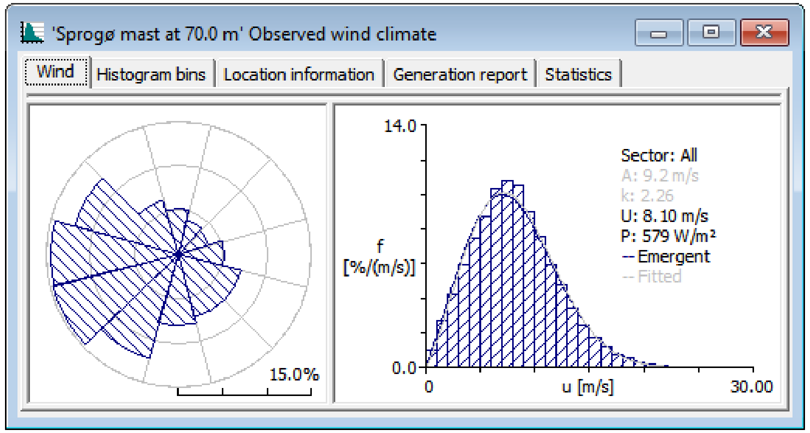
Wind power basics

Measurements

Time series



Wind climate



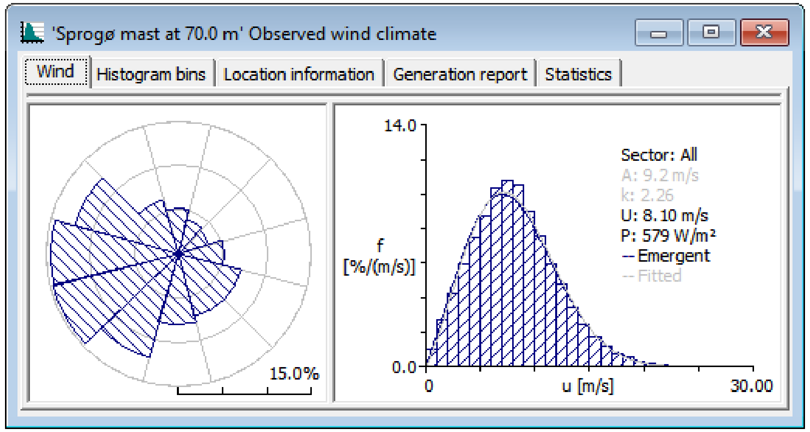
Wind speed distribution @ hub height

- Wind direction distribution (wind rose)
- Sector-wise wind speed distributions

Intrinsic characteristics of the atmosphere at a site

Wind power basics (continued)

Wind climate



Intrinsic characteristics of the atmosphere at a site

Mean wind speed (m/s):

$$\overline{\mathrm{U}} = \sum u(t)$$

wind speed (m/s)

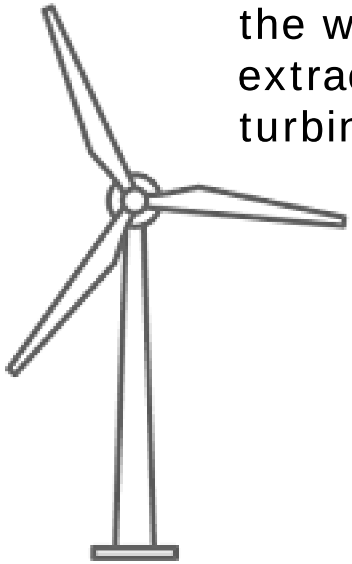
Mean wind power density (W/m^2):

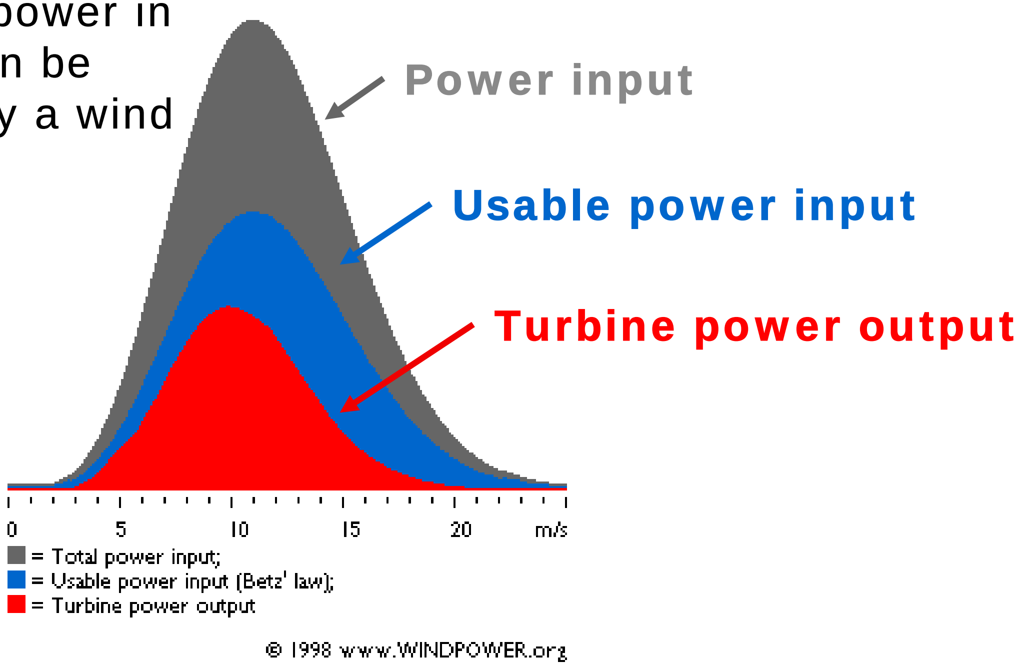
$$\overline{\mathrm{PD}} = \frac{1}{2} \sum \rho(t) u^3(t) \simeq \frac{1}{2} \bar{\rho} \sum u^3(t)$$

air density (kg/m^3)

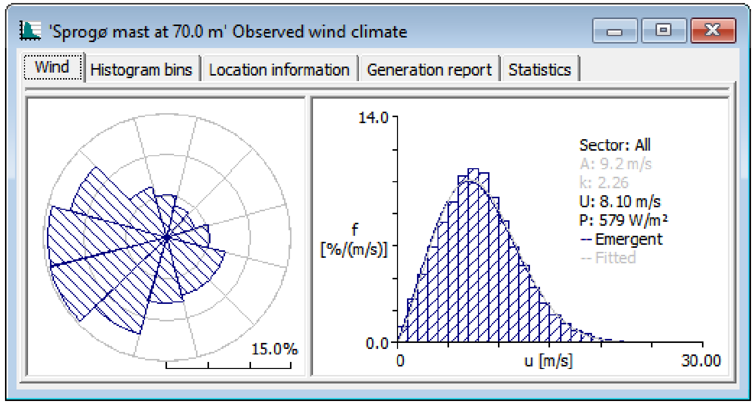
Wind power basics (continued)

Not all the power in the wind can be extracted by a wind turbine

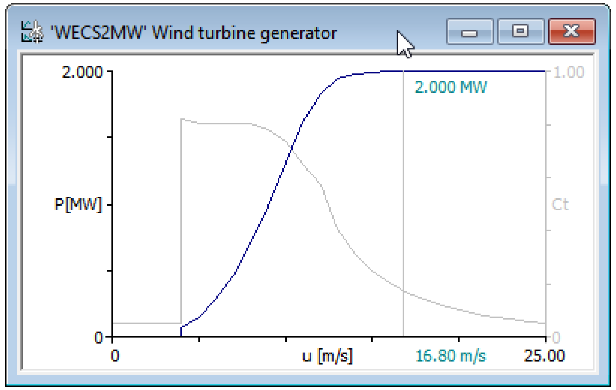




Wind climate



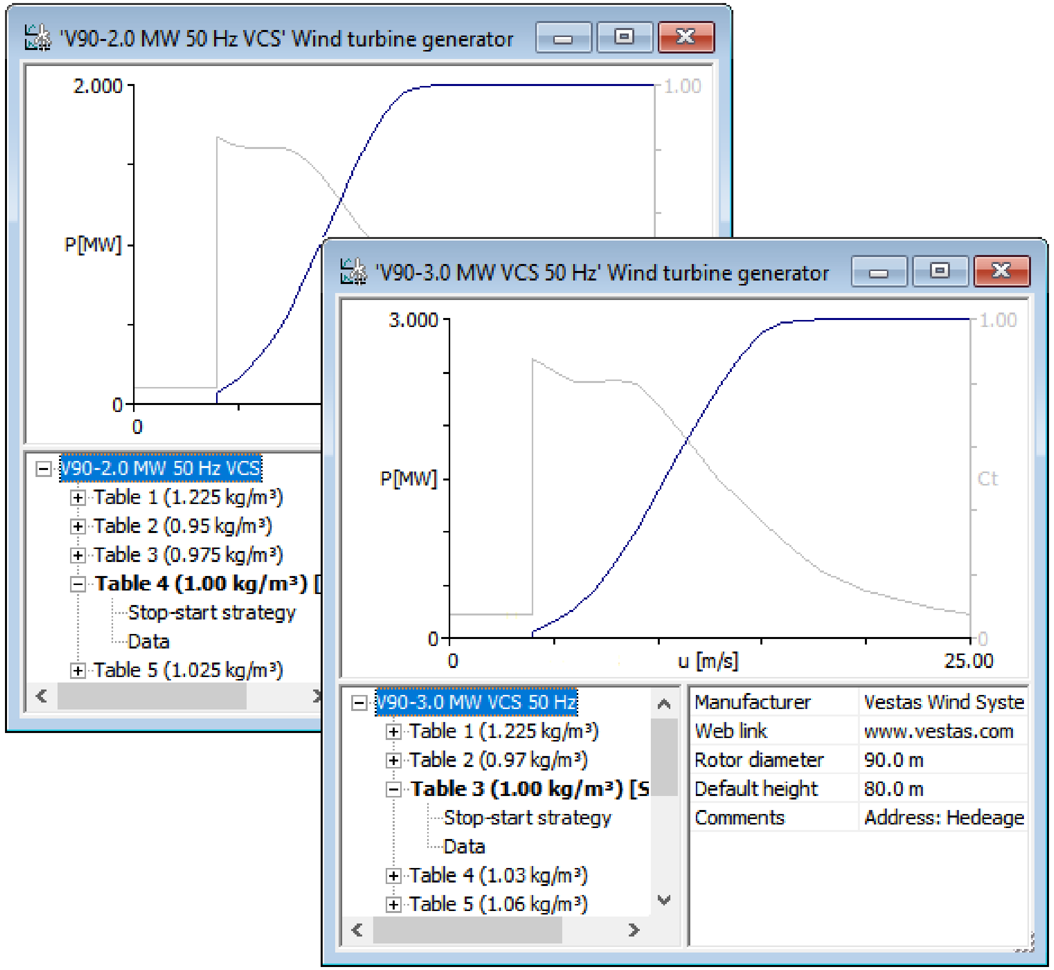
Turbine characteristics



Energy output

Comparison of two V90 Vestas turbines rated 2 MW and 3 MW

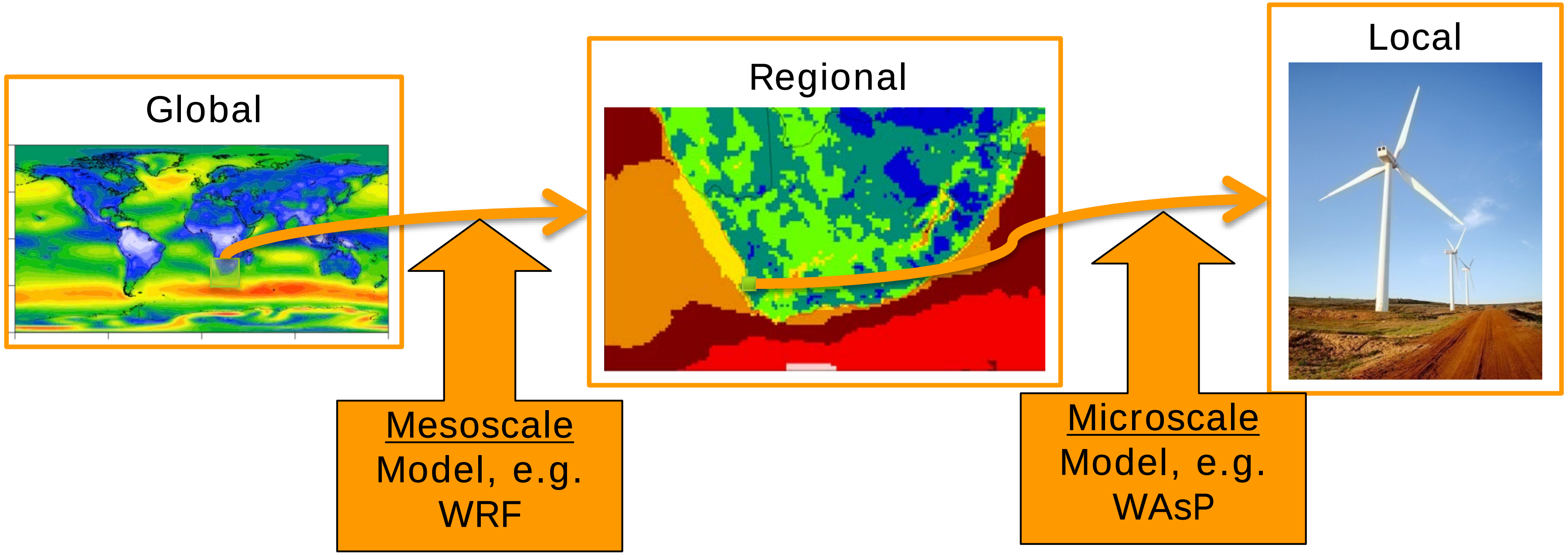
Vestas V90 wind turbine



Parameter	V90 2-MW	V90 3-MW
Wind speed	7.87 ms^{-1}	7.87 ms^{-1}
Power density	427 Wm^{-2}	427 Wm^{-2}
Energy yield	6.881 GWh	7.831 GWh
Capacity factor	39%	30%
Full-load hours	3441 h	2610 h

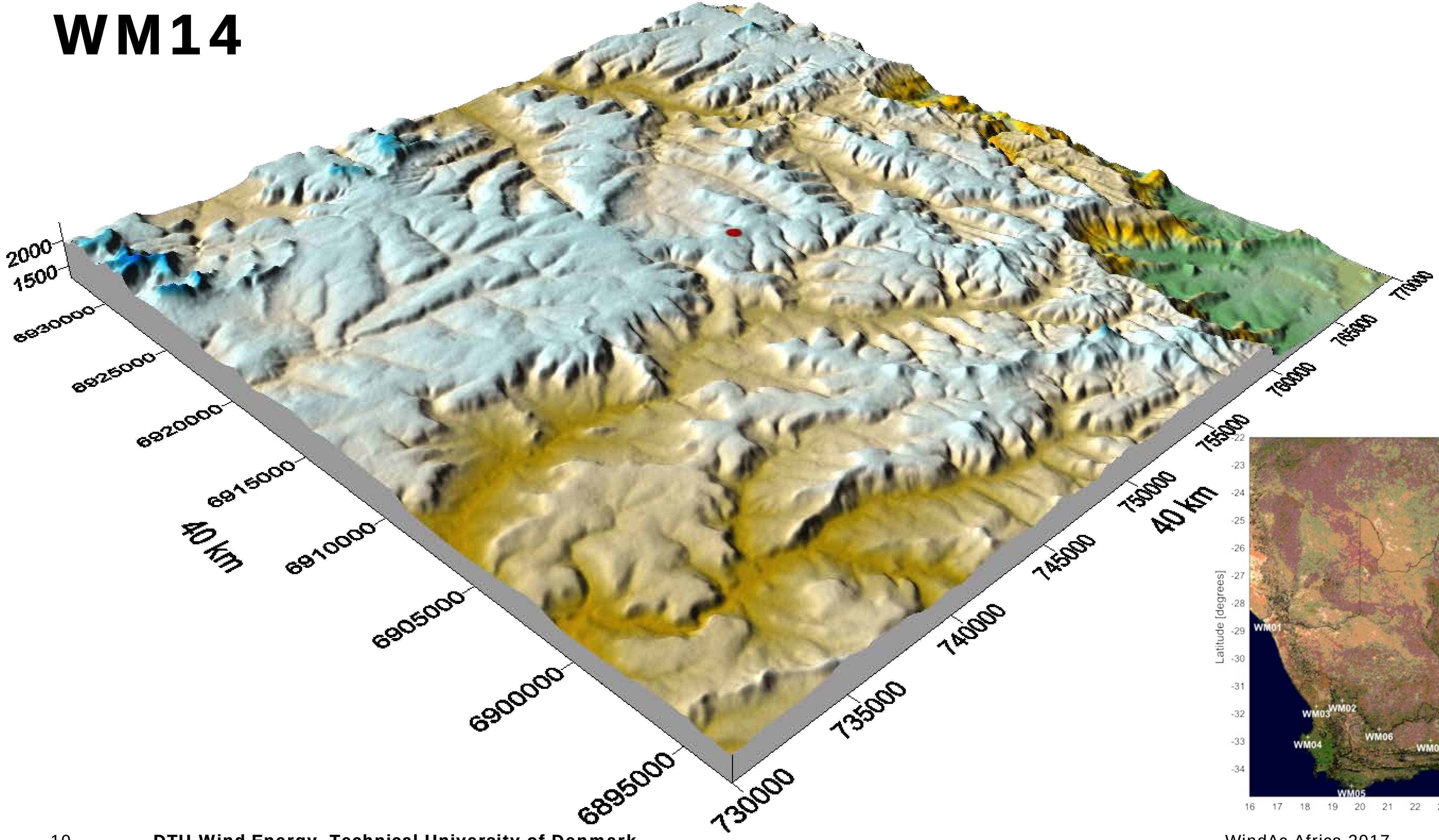
Let’s look at some maps…

- These are derived from model data, using usual DTU downscaling method



- Mesoscale model: Weather, Research and Forecasting (WRF) simulations at **5 km x 5 km** grid spacing
- WRF-derived wind climatologies are used to drive the microscale model WAsP, at a horizontal grid spacing of **250 m x 250 m**

WM14


2000
1500
6930000
6925000
6920000
6915000
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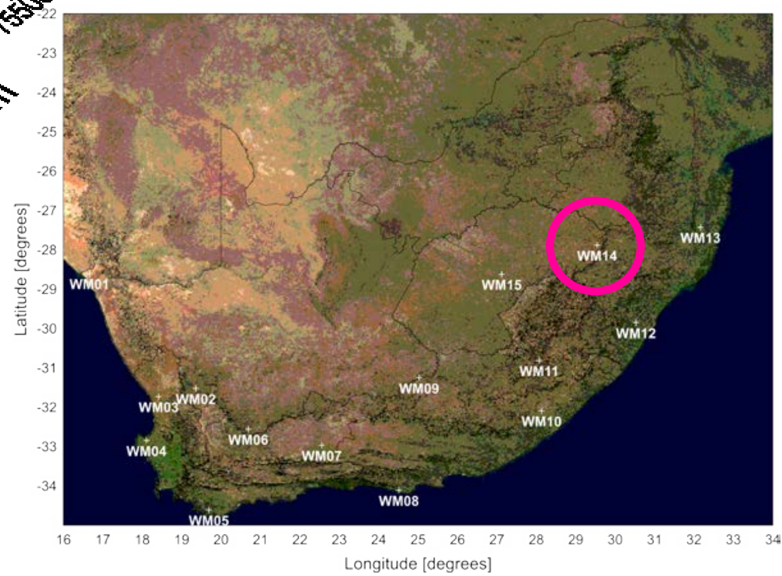
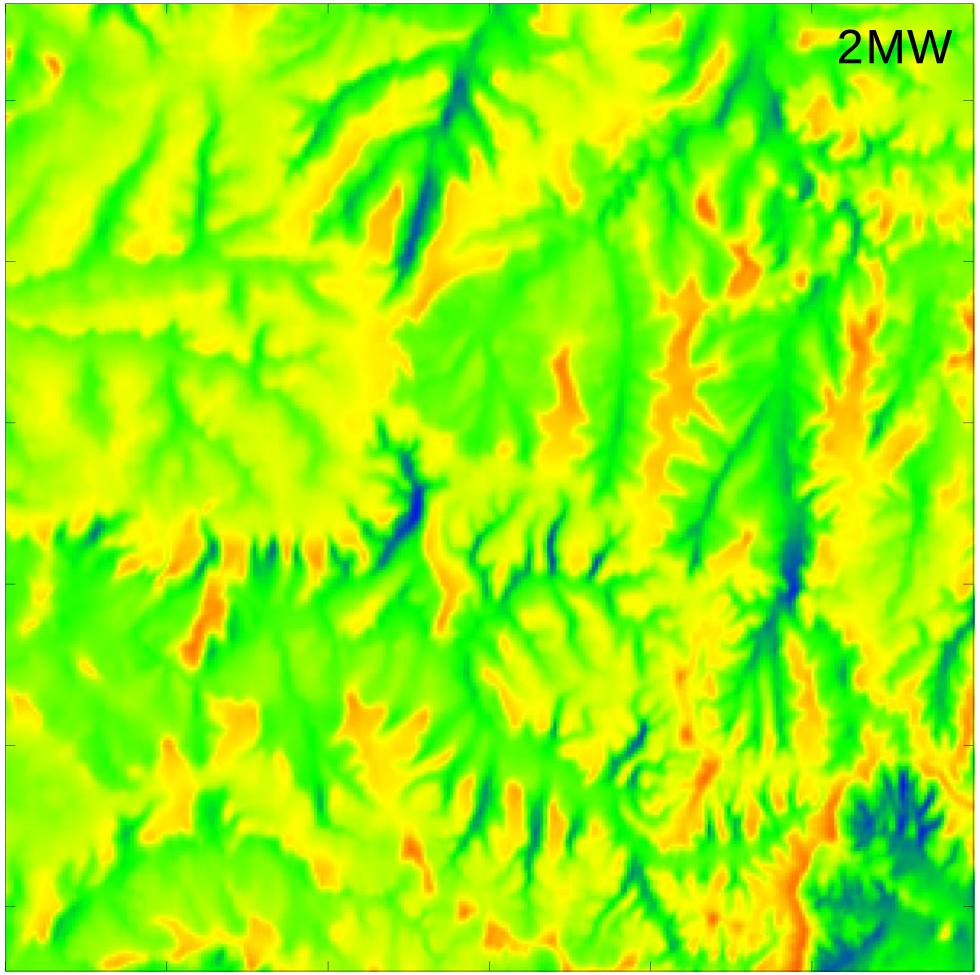
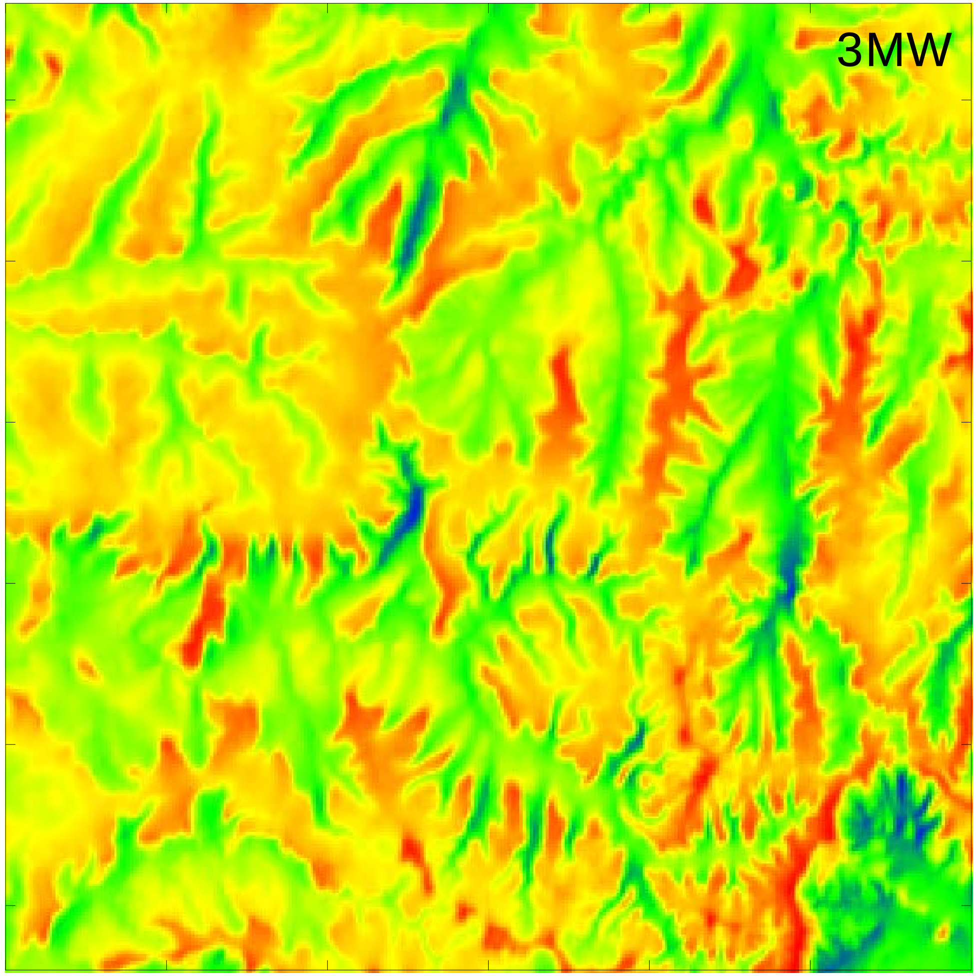
6900000
6895000
40 km
730000
735000
740000
745000
750000
755000
760000
765000
40 km

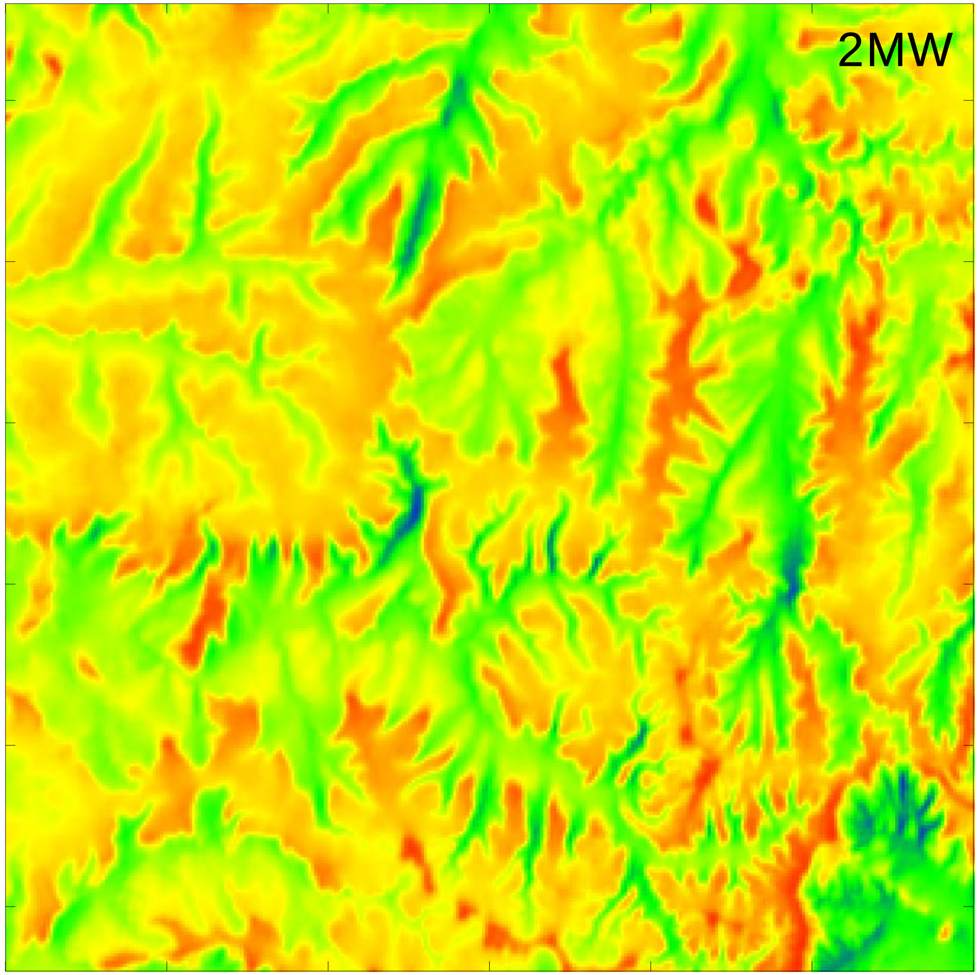

-22
-23
-24
-25
-26
-27
-28
-29
-30
-31
-32
-33
-34
Latitude [degrees]
16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34
Longitude [degrees]
WM01
WM02
WM03
WM04
WM05
WM06
WM07
WM08
WM09
WM10
WM11
WM12
WM13
WM14
WM15

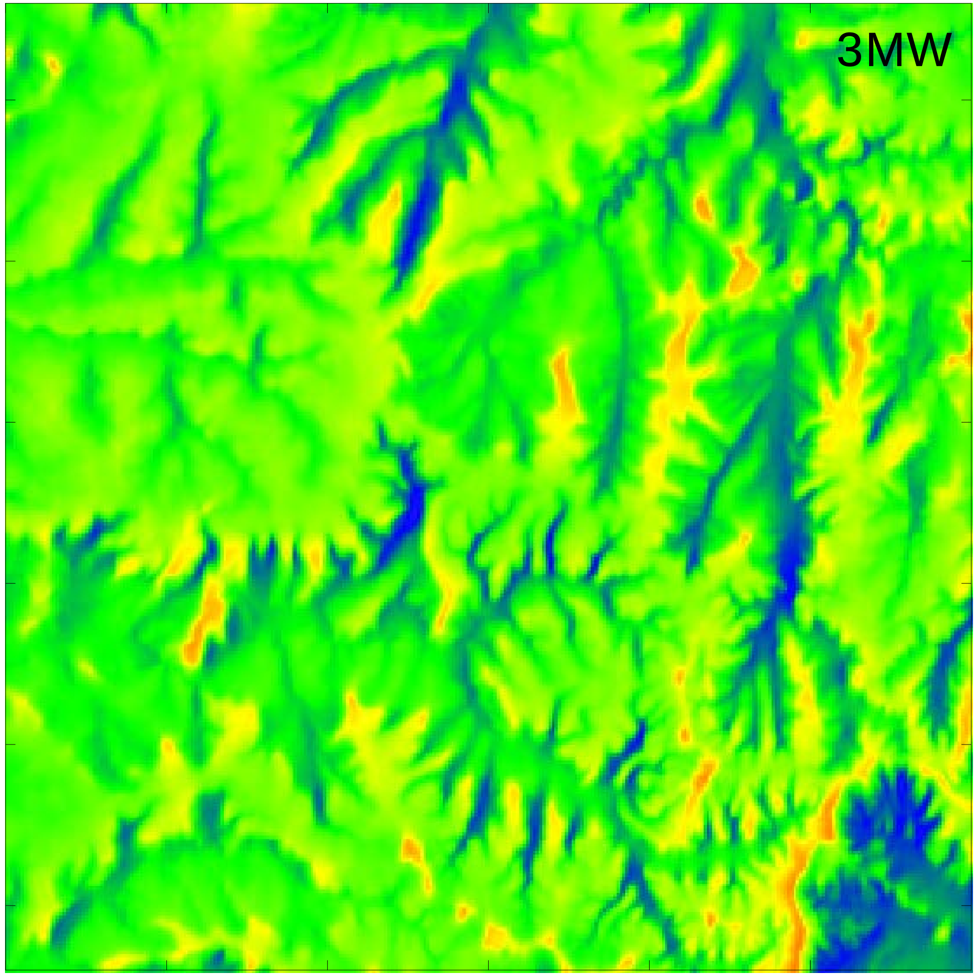
WM 14 – 2-MW and 3-MW energy yield maps
(0-12 GWh/y)





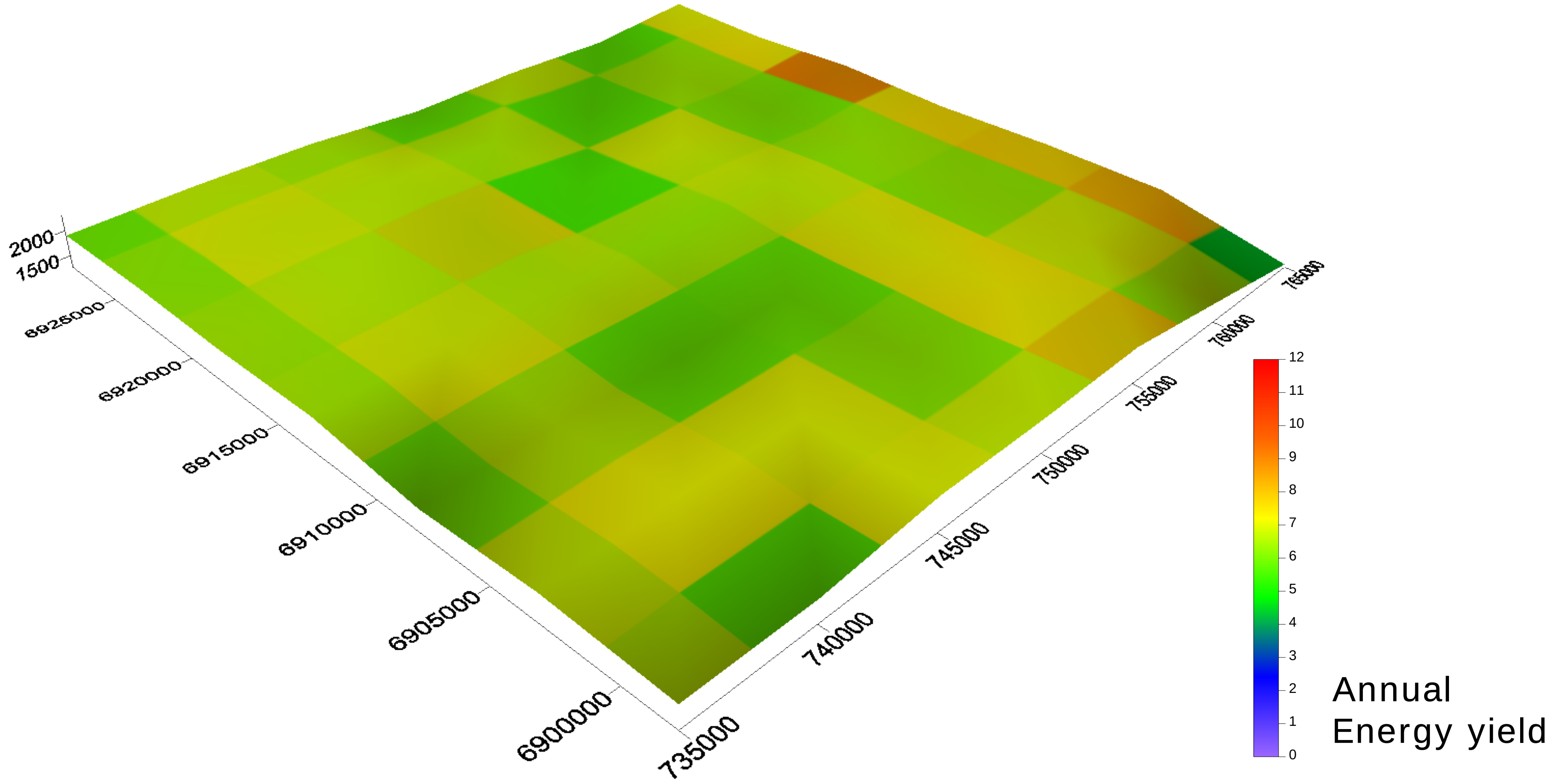
WM 14 – 2-MW and 3-MW capacity factors (0-0.6)



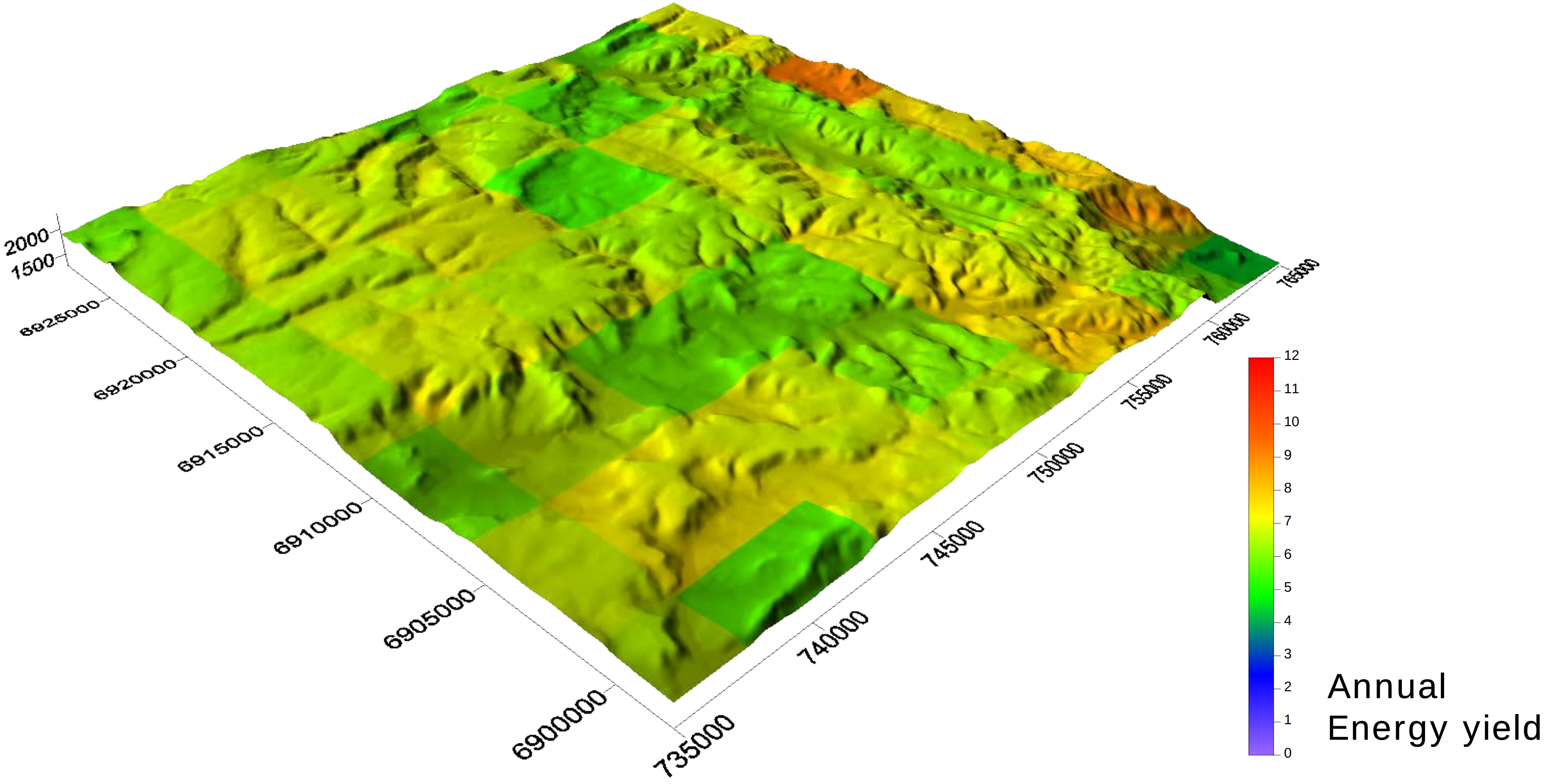


But, this is not the most important factor…

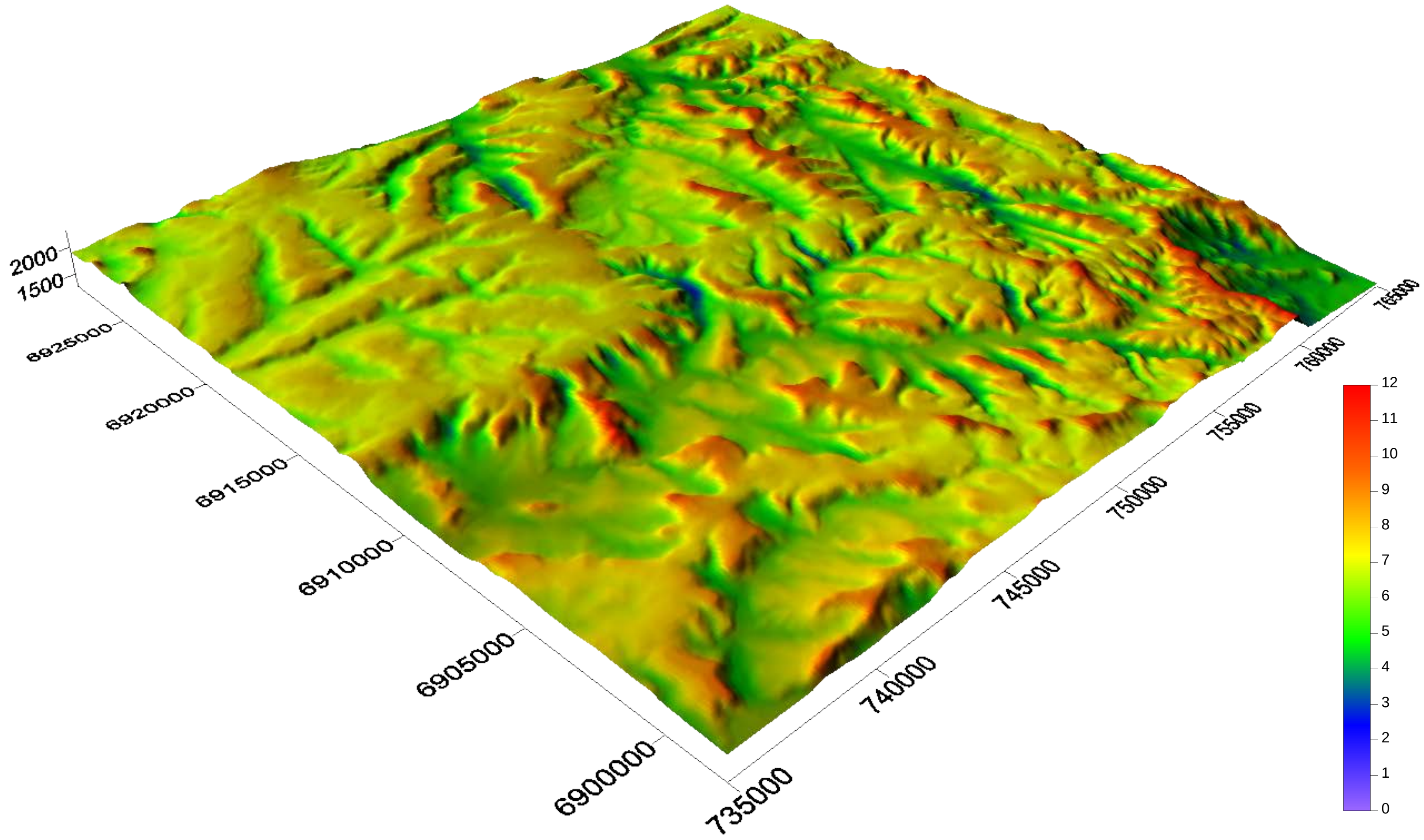
Mesoscale predictions



Mesoscale predictions



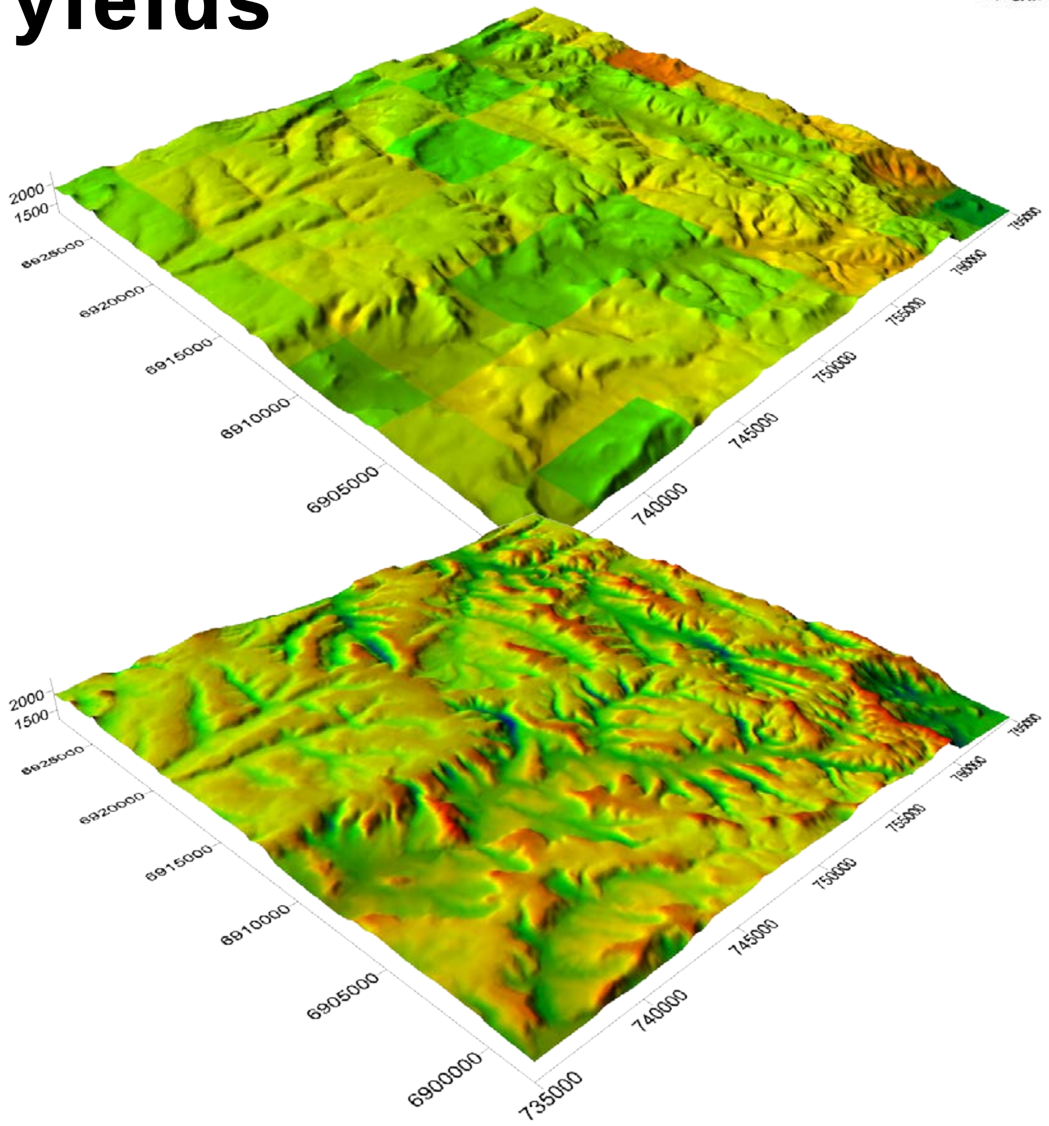
Microscale predictions



Annual Energy yield

Statistics of turbine energy yields

AEP [GWh]	**Meso AEP**	**Micro AEP**
WM14 site	6.6	7.8
Mean of grid	6.7	7.0
Grid range	4.4–9.0	2.7-12.1
90%-tile	7.5	8.6
95%-tile	7.7	9.1



Summary and conclusions

- When visualizing wind atlas data:
  - Intrinsic characteristics of the atmosphere, e.g. mean wind speed, mean power density
  - Power density maps can be deceptive, because PD is integrated from 0-∞ wind speed
  - Energy yield is calculated from wind distributions, and air density is an important factor
  - Other quantities depend on the wind turbine/technology used, e.g. AEP, capacity factor

- Resolution is important:
  - The mesoscale model wind output is **not** the spatial average of the grid speed over a grid
  - Wind turbines **do not** turn with the wind of a mesoscale model
  - Microscale maps resemble reality only when resolution is less than about 100 meters
  - … but the model world is not the real world, and there will be uncertainties.